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INTEGRATED BIOSTRATIGRAPHY OF UPPER MAASTRICHTIAN CHALK AT CHEŁM (SE POLAND)

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Abstract: A 40-m-thick section of chalk exposed in the Chełm quarry (SE Poland) contains a rather poor assemblage of macrofauna and a well diversified assemblage of foraminifers. The planktonic foraminifer assemblages characterized by a considerable number of representatives of *Globigerinelloides* and *Heterohelix* and the presence of *Guembelitria cretacea* indicate the lowest part of the *Guembelitria cretacea* Zone *sensu* Peryt (1980). Benthic foraminifers point out that the strata of the Chełm quarry section can be attributed to the lower part of the Upper Maastrichtian: *i.e.*, the *Gavelinella danica/Brotzenella preacuta* Zone of the European Boreal Province or the *Anomalinoides pinguis* Zone distinguished in Poland (except the Carpathians). The occurrence of ammonites, such as *Hoploscaphites constrictus lviviensis* Machalski, *Hoploscaphites schmidi* (Birkelund), and *Acanthoscaphites varians blaszkiewiczi* Jagt & *al*. indicates that the Chełm succession belongs to the lower part of the *Belemnitella junior* Zone, *i.e.*, to the *Belemnitella junior–Spyridoceramus tegulatus* Zone *sensu* Schulz & Schmid (1983).

The correlation of the Chełm quarry section and the Middle Vistula River Valley section indicates that the equivalent interval of the former section is not exposed in the Middle Vistula River Valley and that it would occur between the Chotcza and Lucimia villages within the lower part of the *Belemnitella junior* Zone, *i.e.*, within the *Belemnitella junior-Spyridoceramus tegulatus* Zone distinguished in NW Germany (Schulz & Schmid,1983).

Key words: biostratigraphy, foraminifers, ammonites, belemnites, chalk, Upper Maastrichtian, Border Synclinorium, SE Poland.

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INTRODUCTION

The Chełm quarry (SE Poland) – a 40-m-thick section of Maastrichtian chalk – is located in the south-eastern part of the Border Synclinorium (Pożaryski, 1997; Świdrowska, 2007; Voigt *et al.*, 2008) (Fig. 1). Despite of an easy access, the Cretaceous exposed in the Chełm quarry and in natural outcrops in the environs of Chełm was subject to very moderate interest of palaeontologists and stratigraphers. Consequently, the previous publications (Sujkowski, 1931; Witwicka, 1958; Alexandrowicz, 1977; Pióro, 2007) are limited in number. Sujkowski (1931) was the first one who mentioned foraminifers occurring in the Cretaceous of Chełm. Subsequently, Witwicka (1958) described from the Chełm IG1 borehole, located about 1 km north of the Chełm city, over 30 species that are now included into the following genera: *Neoflabellina*, *Bolivinoides*, *Pseudouvigerina*, *Reussella*, *Pseudovalvulineria*, *Stensioeina*, *Globorotalites*, *Lingulogavelinella*, *Cibicides*, *Rotalipora*, *Praeglobotruncana*, *Marginotruncana*, *Globotruncana*, *Contusotruncana*, *Archaeoglobigerina*, *Globotruncanita*, and *Planoglobulina.* Witwicka (1958) subdivided the Cretaceous strata of the Chełm IG1 borehole into stages based on the ranges of recognised species. In the Upper Maastrichtian interval (10.6–100 m), she distinguished a zone without *Stensioeina*. Interval without *Stensioeina* has been also recognised by Pożaryska (1954) in the Middle Vistula River Valley section. Alexandrowicz (1977), describing sclerites of octocorrals from this site on the basis of benthic foraminifers, supposed a mid-Late Maastrichtian age of these strata. Recently, Pióro (2007) has confirmed the Late Maastrichtian age of the Chełm section on the basis of planktonic foraminifers and assigned the deposits from the Chełm quarry to the lower part of the *Guembelitria cretacea* Zone *sensu* Peryt (1980).

The Late Maastrichtian age of the Chełm strata are also supported by their ammonite fauna (Machalski, 2005; Machalski *et al.*, 2008). Other faunal groups have not been the

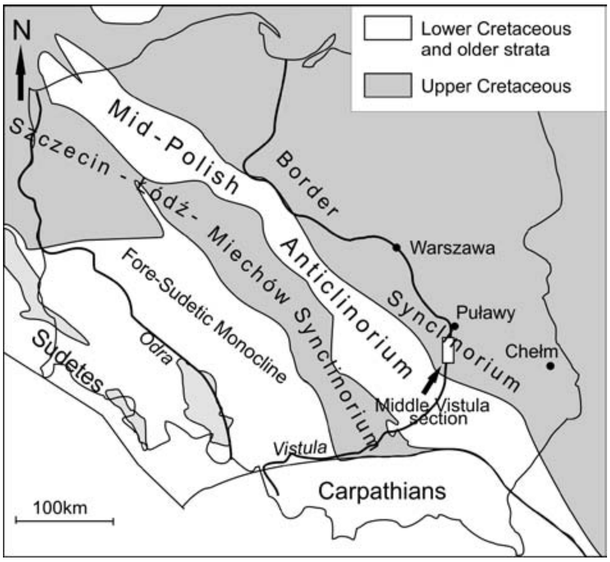

Fig. 1. Geological pre-Cenozoic sketch map of Poland (simplified by Voigt *et al.*, 2008, after Pożaryski *et al.*, 1979), showing the location of Chełm and the Middle Vistula River Valley section

subject of detailed stratigraphical-palaeontological studies so far.

The aim of this paper is to establish an integrated detailed stratigraphy of the Chełm section based on microfauna (planktonic and benthic foraminifers) and macrofauna (ammonites and belemnites) and to precisely correlate it with the "classical" section of the Upper Cretaceous along the Middle Vistula River Valley between Annopol and Puławy, the most complete naturally exposed section of the Upper Cretaceous in Europe.

GEOLOGICAL SETTING

The working chalk quarry of the "Chełm Cement Plant" is located east of the Chełm city, approximately 2 km from the railway station Chełm-Miasto (Fig. 2). The region is a hilly land, and in the depressions marls and chalk occur (Harasimiuk, 1975) while the hills are composed of slightly younger Maastrichtian opokas. In the borehole Chełm IG1, the Upper Maastrichtian chalk is 89.4 m thick, and also the Lower Maastrichtian (69.2 m thick) is developed in the chalk facies, with three intercalations of marls (Lendzion, 1960). The Upper Maastrichtian sediments have been deposited in an epicontinental sea, which had the greatest extent at the end of the early Late Maastrichtian. Then, during the latest Maastrichtian, it shranked and its coastline was lying probably along the Bug River (Krassowska, 1997). There, a well developed hardground bed occurs at the boundary with the overlying Palaeocene strata (Harasimiuk *et al.*, 1984).

The Chełm quarry has four exploitation levels (II, III, IV, and V; from top to bottom) and a dewatering dig, which for the purpose of this paper is designated as level VI (Fig. 2).

Chalk is light-grey to creamy in colour when fresh and almost white when dried. Cherts, which are characteristic

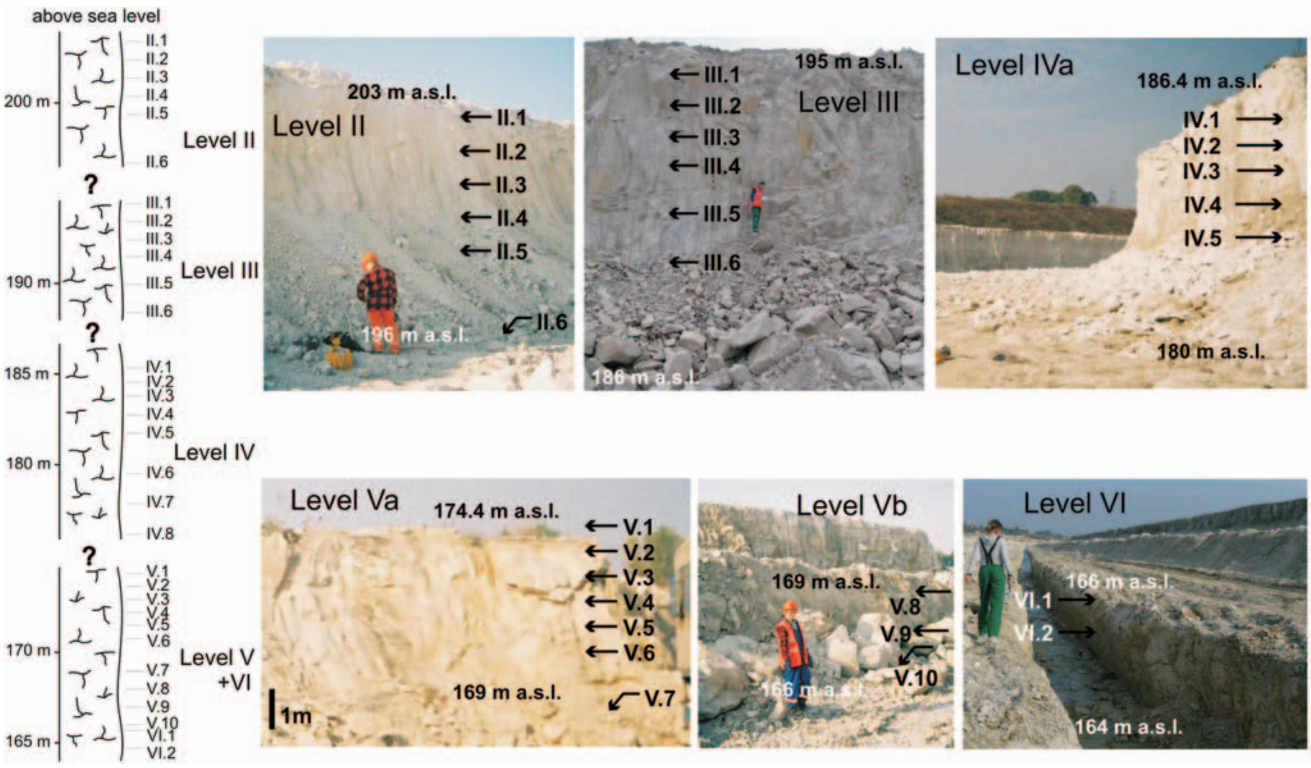

Fig. 2. Location of samples in the Chełm quarry section. Roman numbers indicate the exploitation levels, and the Arabic numbers show samples within particular exploitation levels (from top to bottom)

for chalk facies elsewhere, are lacking in the quarry as already recognised by Siemiradzki (1909). The chalk strata are lying almost horizontally as indicated by fossils (such as sponges or echinoids) buried in growth position. The chalk of the Chełm quarry is macroscopically quite homogeneous and because any specific lithological features are lacking, for the purpose of this paper, the exploitation levels will be used as a reference. It should be mentioned, however, that the chalk of levels IV–VI is strongly bioturbated, with abundant *Zoophycos*, *Chondrites* and pyritized burrows, while in levels III and II trace fossils are lacking or rare; thus it results that the outcropping section is clearly bipartite.

MATERIAL AND METHODS

Samples were taken from fresh quarry walls at 1 m interval; in total 40 samples were analysed micropalaeontologically. Each sample was 0.5 kg in weight. The Roman numbers indicate the exploitation level and the Arabic ones show the succeeding numbers for each level, with "1" indicating the top of a level (Fig. 2).

For micropalaeontological analyses, samples were processed using the Glauber's salt. An aliquot of about 300 specimens from the >63 μm size fraction was picked for quantitative analysis. The figured specimens are deposited in the Institute of Paleobiology, Polish Academy of Sciences, Warszawa (ZPAL F. 61).

In this study, foraminifers were identified at the generic level according to Loeblich and Tappan's (1987) classification.

RESULTS

Foraminifers

Planktonic foraminifers (Figs 3D, F; 4 A–T; 5 A–K)

The planktonic foraminifer assemblages from the Chełm quarry are characterised by (1) a considerable number of representatives of *Globigerinelloides* Cushman & Ten Dam: *Globigerinelloides multispinus* (Lalicker), *G. abberantus* (Neckaja), *G. prairiehillensis* Pessagno; (2) a considerable amount of heterohelicids: *Heterohelix striata* (Ehrenberg), *H. globulosa* (Ehrenberg), *H. varsoviensis* (Gawor-Biedowa), *H. ultimatumida* (White), *Laeviheterohelix glabrans* (Cushman); and (3) the occurrence of *Guembelitria cretacea* (Cushman) in the entire section.

The most common are the representatives of *Globigerinelloides*, followed by *Heterohelix*. The abundance of *Heterohelix* taxa increases in the upper part of the section, and in the upper part of level II *Heterohelix* starts to dominate the planktonic foraminifer assemblage (see Fig. 3F). In the lower part of the section (level V), representatives of *Globotruncana* Brotzen: *G. arca* (Cushman), *G.* cf. *rosetta* (Carsey) and of *Contusotruncana* Korchagin: *C. patelliformis* (Gandolfi), *C. fornicata* (Plummer) occur. After a brief interval they first decline in abundance, then disappear in the higher interval. In the lowermost part of the quarry (level VI and the lowest part of level V), *Globotruncanella petaloidea* (Gandolfi) was also found in some abundance, followed by a decline till disappearance in the upper part of the section. *Pseudoguembelina*, *Laeviheterohelix* and *Planoglobulina carseyae* occur in low numbers in level II only.

In level VI, representatives of *Globotruncanella* constitute *ca.* 40% of the planktonic foraminifer assemblages, *Heterohelix ca.* 20%, and *Globigerinelloides* 40% (Fig. 4F). In the lower part of level V, representatives of *Globotruncana* made up several percent of the planktonic foraminiferal assemblages, balanced by a decrease in abundance of *Globotruncanella*, while the amount of *Globigerinelloides* increases and that of *Heterohelix* remains similar (*ca.* 20%). Upward, in the upper part of level V, in levels IV, III, and the lower part of level II, the planktonic foraminiferal assemblage comprises *Globigerinelloides* (*ca.* 80%) and *Heterohelix* (averaging 20% and ranging from several to 30%). In the upper part of level II, *Heterohelix* starts to prevail over *Globigerinelloides* (Fig. 3F).

The abundance of planktonic foraminifers (P/B+P) in the 0.12–0.75 mm fraction averages 20% and ranges from 9% (sample IV.7) to 45% (sample II.3) in the upper part of level II. The highest P/B values in level II are accompanied by an increase in abundance of *Heterohelix*. The P/B values in the 0.06–0.12 mm fraction are higher, 40% on average. The maximum value is 62% (sample II.3) in the upper part of the level II. The planktonic foraminifers of the 0.06–0.12 mm fraction are represented mainly by *Guembelitria*, juvenile specimens of *Globigerinelloides*, and also smaller-sized *Heterohelix*.

Benthic foraminifers (Figs 3E; 5L–W)

The rich assemblage of benthic foraminifers comprises over thirty genera representing both calcareous forms (the most common are: *Cibicidoides*, *Gavelinella*, *Gyroidinoides*, *Anomalinoides*, *Osangularia*, *Pullenia*, *Coryphostoma*, *Valvalabamina*, *Dentalina*, *Nodosaria*, *Praebulimina*) and agglutinated forms (*Ataxophragmium*, *Spiroplectammina*, *Arenobulimina*, *Plectina*, *Heterostomella*, *Tritaxia*, *Gaudryina* among others). Calcareous foraminifers are predominant, usually 70–80% of the benthic foraminiferal assemblages, ranging from a minimum of 51% (sample II.3) to a maximum of 91% (sample V.5).

The benthic foraminiferal assemblages are similar throughout the entire section except for a slight modification noticed in the uppermost part of level II. The most common taxa are representatives of *Cibicidoides* (*ca.* 20%, with a maximum of 34% in sample IV.1 and a minimum of 9% in the upper part of level II), *Gyroidinoides* (*ca.* 15%), *Spiroplectammina* and *Ataxophragmium* (up to twelve or so percent) in the same interval.

Macrofauna (Figs 3A–C; 6 A–C)

The following taxa have been found in the Chełm quarry:

– ammonites: *Hoploscaphites constrictus lviviensis* Machalski (30 specimens, in all levels), *H. felderi* Kennedy (one specimen, level VI), *H. schmidi* (Birkelund) (one specimen, level VI), *Acanthoscaphites varians blaszkiewiczi* Jagt *& al.* (one specimen, level VI) (Dubicka, 2008; Machalski *et al.*, 2008);

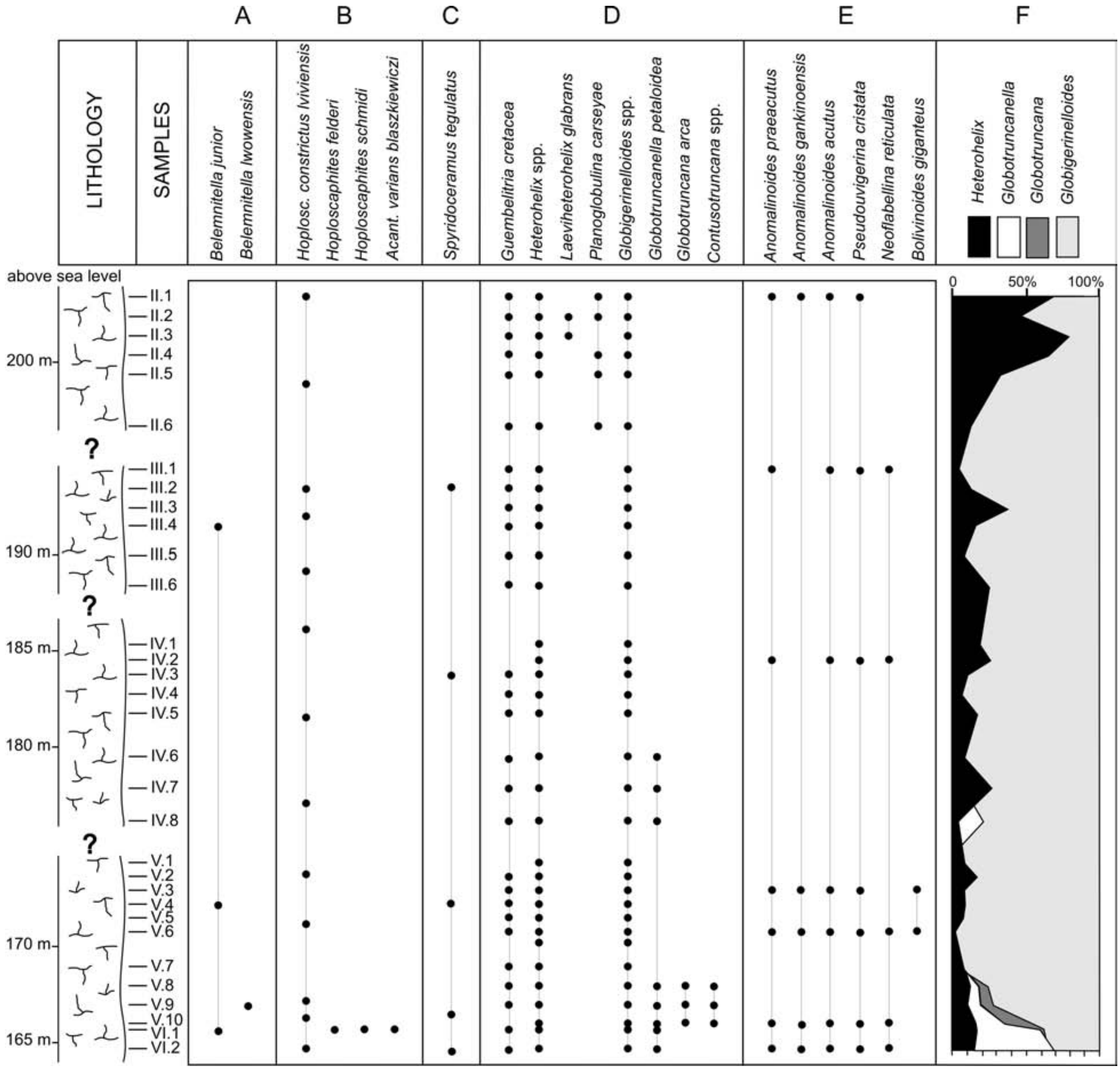

Fig. 3. Distribution of macrofossils and foraminifers in the Chełm section. A – belemnites, B – ammonites (after Machalski *et al.*, 2008), C – inoceramids, D – planktonic foraminifers, E – selected species of benthic foraminifers, F – abundance fluctuations of planktonic foraminifers (very rare taxa are omitted)

– belemnites: *Belemnitella junior* Nowak (three specimens, levels VI, V and III), *B. lwowensis* Naidin (one specimen, level V);

– bivalves: *Spyridoceramus tegulatus* (Hagenow), *Hyotissa semiplana* (Sowerby), *Barbatia tenuistriata* (v. Münster), *Plagiostoma cretacea* (Woods), *Spondylus dutempleanus* d'Orbigny, *Pycnodonte resiculare* (Lamarck), *Rhynchostreon* sp., *Spyridoceramus tegulatus* (Hagenow) (all levels);

– brachiopods: *Carneithyris* sp., *Cretirhynchia* sp. (all levels);

– sponges: *Rhizopoterion cribosum* (Phillips) (all levels);

– echinoids: *Echinocorys* sp. (all levels).

Macrobenthic fauna is the same in all levels, however, its abundance is not constant throughout: the most common fauna was found in levels VI and V, and it is very rare in levels II and III. A great abundance of echinoids was observed in levels VI and V, and it seems likely that it is even possible to distinguish a bed with echinoids in the middle of level Vb, whereas in the upper levels echinoids are rare.

DISCUSSION

Belemnites and ammonites

The two belemnite species found in the Chełm quarry, *Belemnitella junior* Nowak and *B. lwowensis* Naidin, are known only from the Upper Maastrichtian of Europe (Christensen *et al.*, 2004). At Hemmoor near Hamburg (North Germany), *B. junior* Nowak appears in the lowest part of the Upper Maastrichtian and continues up to the middle part of

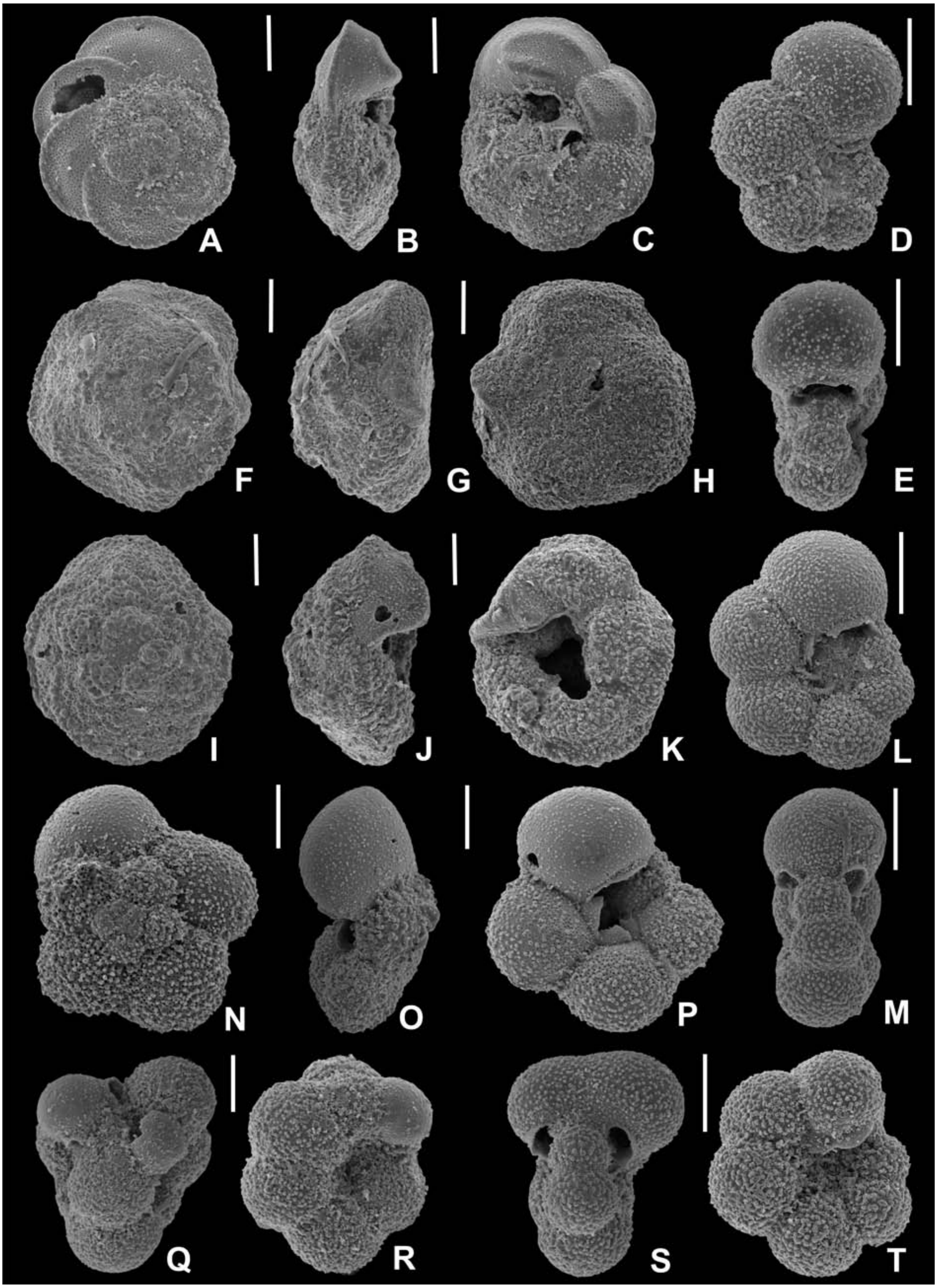

Fig. 4. Planktonic foraminifers. **A–C.** *Globotruncana arca* (Cushman, 1926); A – spiral, B – edge and C – umbilical views; sample V.10; **D, E.** *Globigerinelloides prairiehillensis* Pessagno, 1967; D – side view; E – edge view; sample V.10; **F–H.** *Contusotruncana patelliformis* (Gandolfi, 1955); F – spiral, G – edge and H – umbilical views; sample V.10; **I–K.** *Contusotruncana fornicata* (Plummer, 1931); I – spiral, J – edge and K – umbilical views; sample V.10; **L, M.** *Globigerinelloides abberantus* (Neckaja, 1948); L – side view; M – edge view; sample III.1; **N–P.** *Globotruncanella petaloidea* (Gandolfi, 1955), N – spiral, O – edge and P – umbilical views; sample VI.1; **Q–T.** *Globigerinelloides multispinus* (Lalicker, 1948); Q, S – edge view; R, T – side view; sample III.1. Scale bar indicates 100 μm

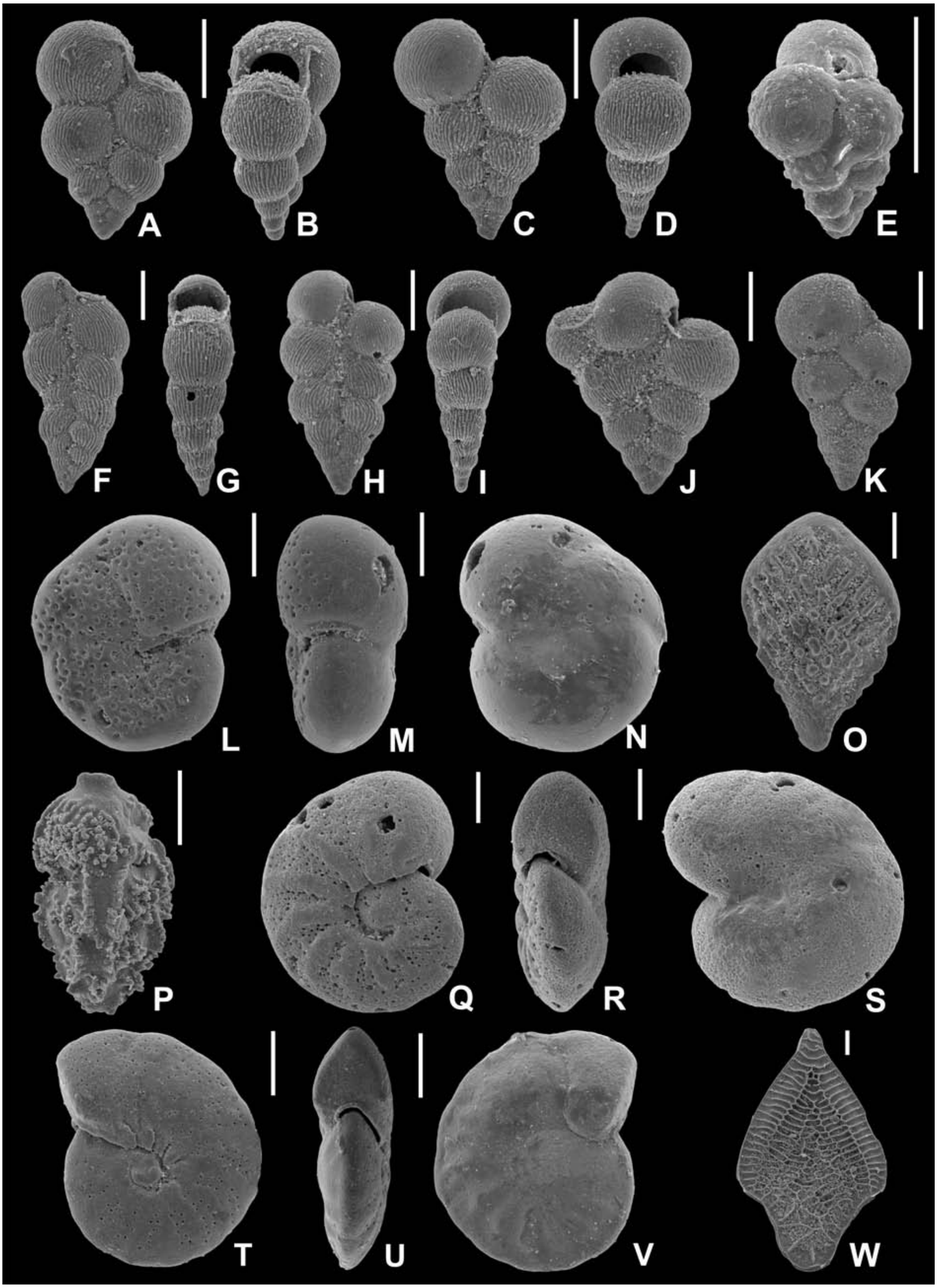
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Fig. 5. Planktonic and benthic foraminifers from the upper Maastrichtian chalk from the Chełm quarry. **A, B.** *Heterohelix ultimatumida* (White, 1929); A – side view; B – edge view; sample II.3; **C, D.** *Heterohelix striata* (Ehrenberg, 1840); C – side view; D – edge view; sample II.3; **E.** *Guembelitria cretacea* Cushman, 1933; side view; sample II.3. **F, G.** *Heterohelix varsoviensis* Gawor-Biedowa, 1992; F – side view; G – edge view; sample II.3; **H, I.** *Heterohelix striata* (Ehrenberg, 1840); H – side view; I – edge view; sample II.3; **J.** *Planoglobulina carseyae* (Plummer, 1931); side view; sample II.3; **K.** *Laeviheterohelix glabrans* (Cushman, 1938); side view; sample II.3; **L–N.** *Gavelinella gankinoensis* (Neckaja, 1948); L – spiral, M – edge and N – umbilical views; sample II.1; **O.** *Bolivinoides giganteus* Hiltermann & Koch, 1950; side view; sample II.1; **P.** *Pseudouvigerina cristata* (Marsson, 1878); side view; sample II.1; **Q–S.** *Anomalinoides praeacutus* (Vasilenko, 1961); Q – spiral, R – edge and S – umbilical views; sample II.1; **T–V.** *Anomalinoides acutus* (Plummer, 1926); T – spiral, U – edge and V – umbilical views; sample II.1; **W.** *Neoflabellina reticulata* (Reuss, 1851); side view; sample II.1. Scale bar indicates 100 μm

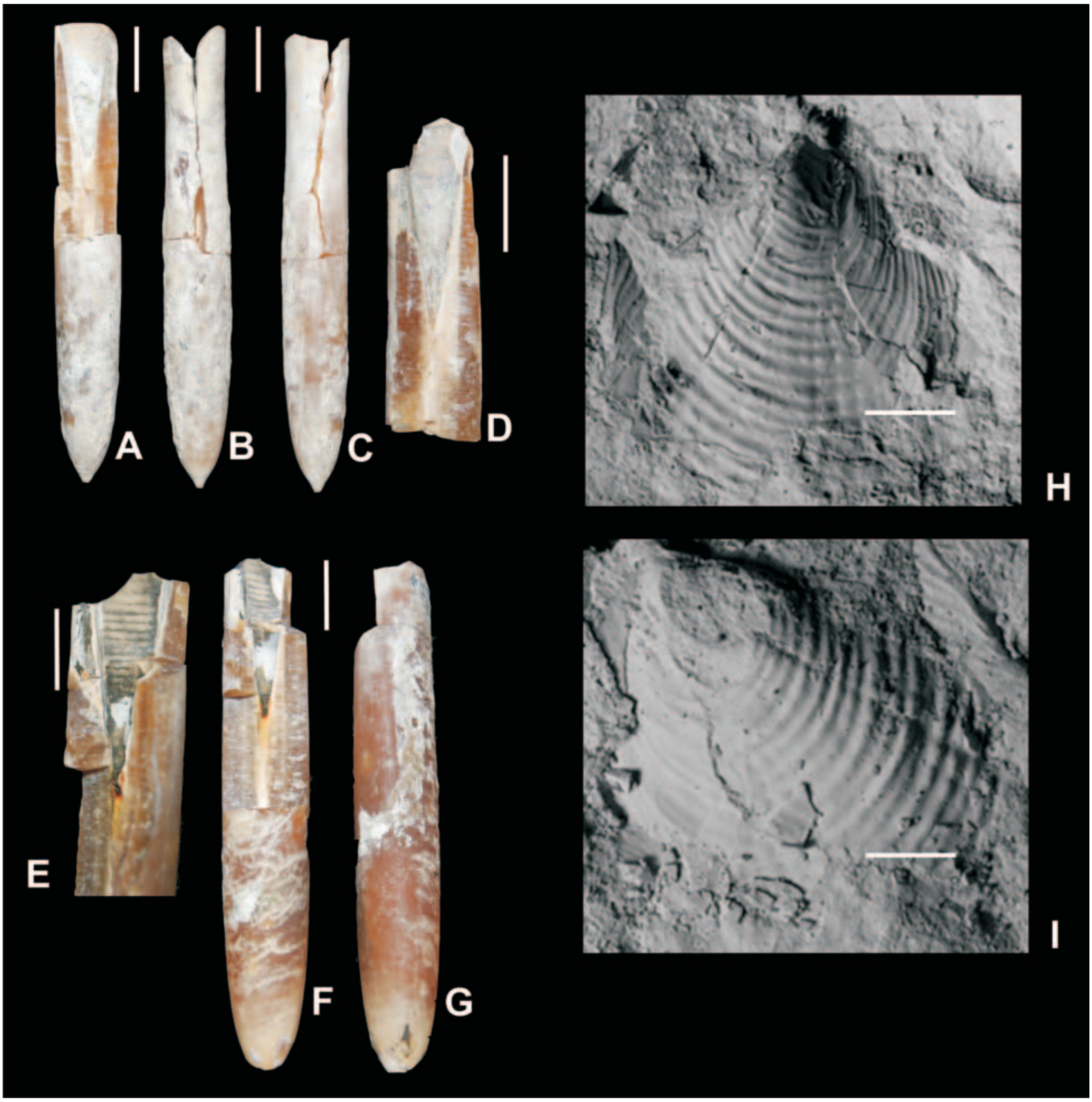

Fig. 6. **A–D.** *Belemnitella lwowensis* Naidin, 1952; A – lateral view; B – ventral view; C – dorsal view; D – view of the split anterior end, showing the internal characters; level V; **E–G.** *Belemnitella junior* Nowak, 1913; E – view of the split anterior end, showing the internal characters; F – ventrolateral view; G – dorsolateral view; level V; **H, I.** *Spyridoceramus tegulatus* (Hagenov, 1842); H – imprint of the shell, I – mould; level IV. Scale bar indicates 1 cm

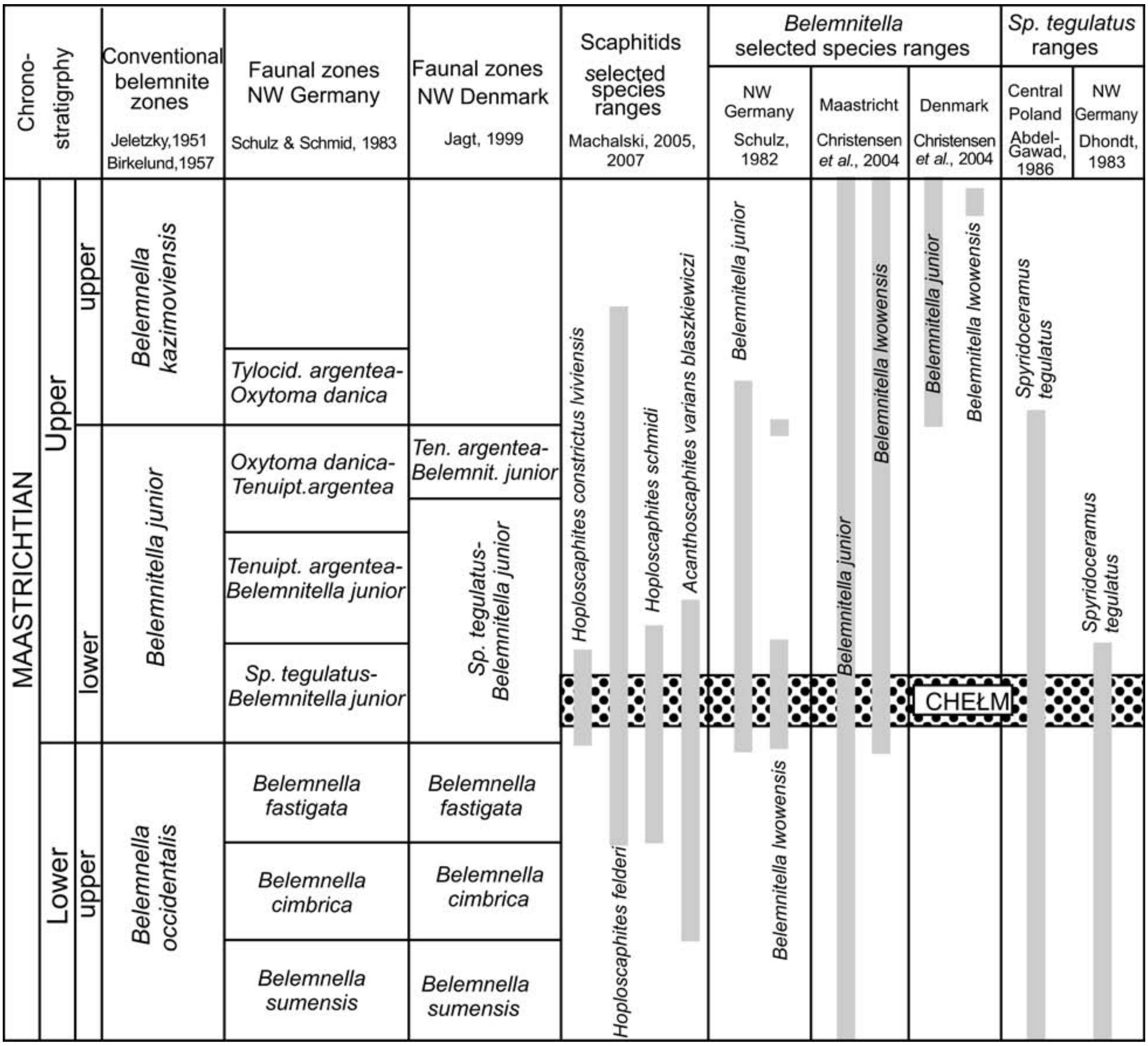

Fig. 7. Stratigraphical ranges of belemnites and ammonites recorded in the Chełm quarry section and in various localities, plotted against the conventional belemnite zonal scheme and faunal zones from the NW Germany and Denmark. Dotted bar shows the interval of the Chełm quarry. *Sp. tegulatus – Spirydoceramus tegulatus*

the *Belemnella kazimiroviensis* Zone (Fig. 7); *Belemnella lwowensis* Naidin occurs in the lowest part of the Upper Maastrichtian and again in the middle part of the Upper Maastrichtian (Christensen *et al.*, 2004). In the environs of Maastricht, *B. lwowensis* appears at the Lower/Upper Maastrichtian boundary, while *B. junior* Nowak occurs from the base of the Maastrichtian. Both species range up to the end of the Maastrichtian (Christensen *et al.*, 2004). On the other hand, Keutgen (1996) described specimens of *B. junior* Nowak from the Lower Maastrichtian but, according to Machalski *et al.* (2007), they appear to be redeposited and thus their age is uncertain. In Denmark, *B. junior* Nowak is recorded in the upper part of the Upper Maastrichtian, *i.e.* in the *B. kazimiroviensis* Zone, while the range of *B. lwowensis* Naidin is confined to the uppermost part of that zone (Christensen *et al.*, 2004).

Christensen (1996) indicated that the boundary between the *Belemnitella junior* and *Belemnella kazimiroviensis* zones is diachronous. The first appearance of *B. kazimiroviensis* (Skołozdrówna), which defines the lower boundary of the nominal zone as well as the lower boundary of the upper part of the Upper Maastrichtian, varies throughout Europe. In Eastern Europe it appears much earlier than in Western Europe and, therefore, the underlying *B. junior* Zone in Poland is characterized by a stratigraphical range shorter than in Western Europe.

Machalski (2005) analysed the occurrence of *Hoploscaphites constrictus lviviensis* Machalski in the Chełm quarry and in the quarries near Lviv and ascribed this subspecies to the *Belemnitella junior-Spyridoceramus tegulatus* Concurrent Range Zone *sensu* Schulz & Schmid (1983). Abdel-Gawad (1986) recorded *Spyridoceramus tegulatus* (Hagenow) to occur in Poland in the entire *B. junior* Zone; however, considering the shorter range of *B. junior* Zone in Poland than in Western Europe, the co-occurrence of *Belemnitella junior* Nowak and *Spyridoceramus tegulatus* (Ha-

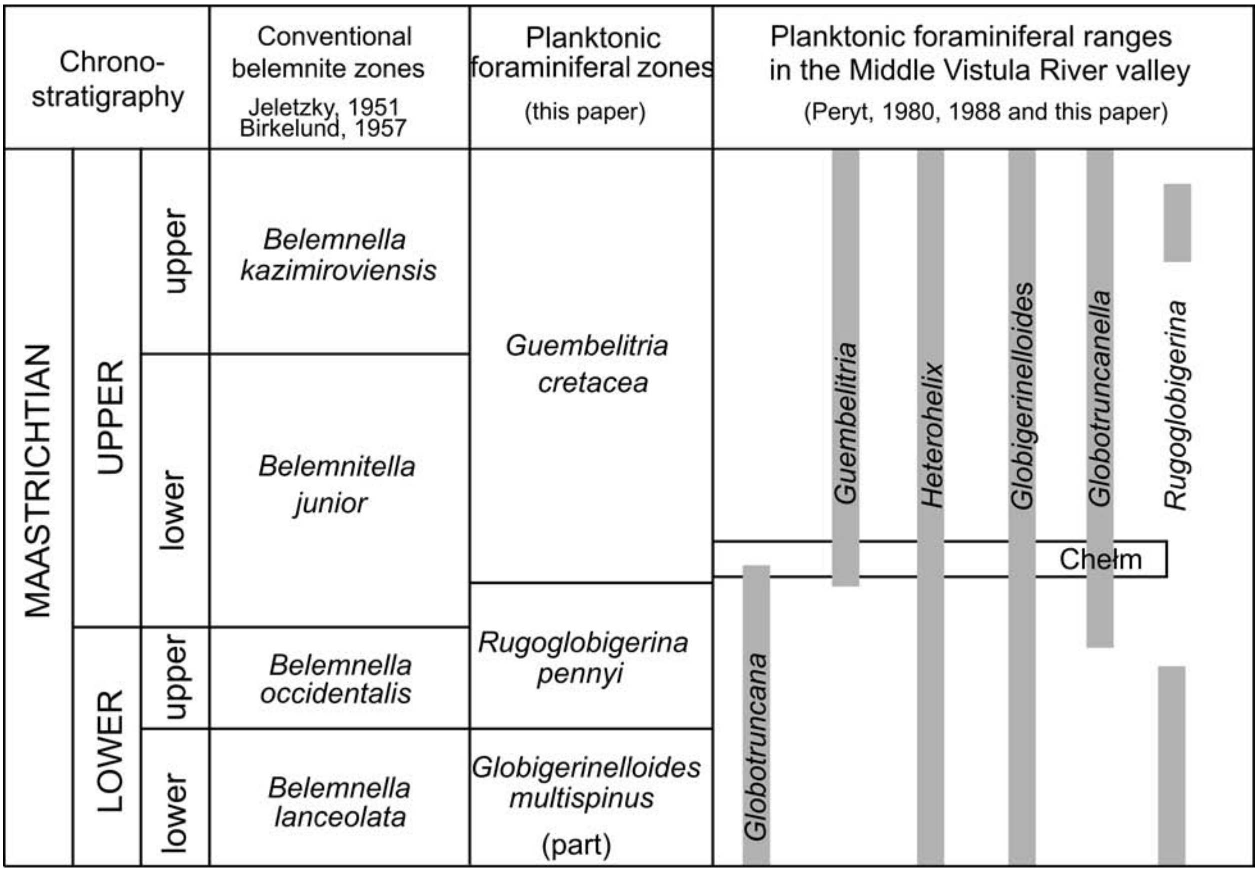

Fig. 8. Correlation of conventional belemnite zones and planktonic foraminiferal zones plotted against the planktonic foraminiferal ranges from the Middle Vistula River Valley (Peryt, 1980, 1988) and those recorded in the Chełm quarry section (this paper)

genow) does not indicate the lowermost part of the *Belemnitella junior* Zone as in the case of the Hemmoor section (see Fig. 7). The co-occurrence of ammonites: *Hoploscaphites constrictus lviviensis* Machalski, *H. schmidi* (Birkelund), and *Acanthoscaphites varians blaszkiewiczi* Jagt *et al.* indicates that the Chełm succession belongs to the lower part of the *Belemnitella junior* Zone, *i.e.*, to the *Belemnitella junior-Spyridoceramus tegulatus* Zone distinguished in NW Germany (Schulz & Schmid, 1983).

Concluding, the deposition interval of the chalk section from the Chełm quarry can be located within the lowermost part of the Upper Maastrichtian (Fig. 7).

Planktonic foraminifers

Peryt (1980) distinguished ten zones of planktonic foraminifers in Cenomanian to Maastrichtian strata of the Middle Vistula River Valley, and the Maastrichtian deposits were included into three zones: the *Globigerinelloides multispinus* Zone (Upper Campanian and lower part of Lower Maastrichtian), the *Rugoglobigerina pennyi* Zone (upper part of Lower Maastrichtian), and the *Guembelitria cretacea* Zone (Upper Maastrichtian). In this paper, this subdivision is followed (Fig. 8).

The *Rugoglobigerina pennyi* Zone is defined as an interval from the first appearance of *Rugoglobigerina pennyi* (Brönnimann) to the first appearance of *Guembelitria cretacea* (Cushman). This zone is characterized by a sudden bloom of foraminifers belonging to *Rugoglobigerina* in the lower part and by a moderate abundance peak in the upper part where rugoglobigerinids occur associated with abundant *Globigerinelloides* and in the absence of *Globotruncana* near the upper boundary of the zone (Peryt, 1980). The definition of the *Guembelitria cretacea* Zone is based on the regional total range of the index species *Guembelitria cretacea* (Cushman). The latter zone in the Vistula River section can be easily recognised by abundant *Heterohelix* and continuous record of *Guembelitria*, and by a considerable number of representatives of *Rugoglobigerina* and *Globigerinelloides*, again in the absence of *Globotruncana* (Peryt, 1980).

The co-occurrence of *Guembelitria cretacea* with representatives of *Heterohelix* and *Globigerinelloides* (*G. multispinus*) indicates the lowest part of the *Guembelitria cretacea* Zone *sensu* Peryt (1980) (Fig. 8). In the lower part of the Chełm section, this assemblage also includes some *Globotruncana*, whose presence suggests that the Chełm section straddles the *Rugoglobigerina pennyi/Guembelitria cretacea* zonal boundary or the range of *Globotruncana* locally extends upward to the lowermost part of the *Guembelitria cretacea* Zone (Fig. 8).

Peryt (1980) equated the boundary between the *Guembelitria cretacea* and *Rugoglobigerina pennyi* zones to the Lower-Upper Maastrichtian boundary. The boundary be-

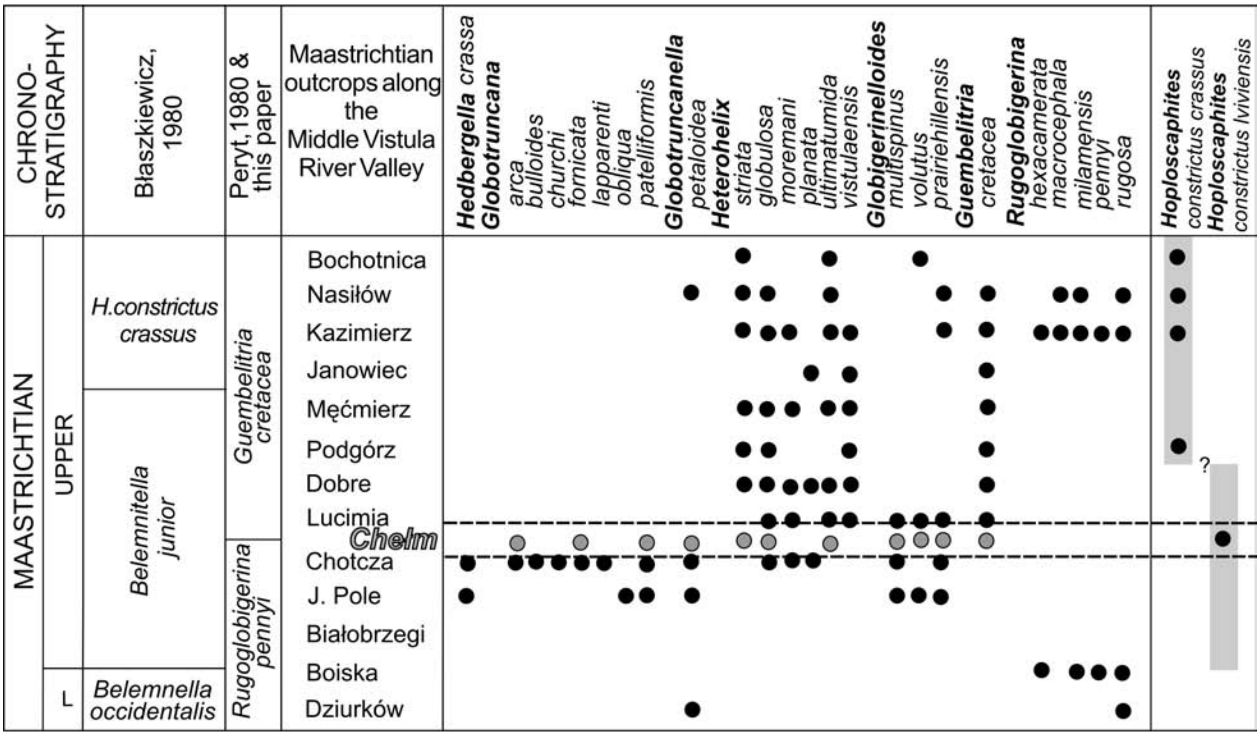

Fig. 9. The occurrence of planktonic foraminifers in the Middle Vistula River Valley section (after Peryt, 1980) and in the Chełm quarry section, plotted against the macrofaunal zonation (after Błaszkiewicz, 1980) and showing the inferred stratigraphical position of the latter section

tween these two zones in the Vistula River Valley is located between the localities of Chotcza and Lucimia (see Fig. 9), and, according to Błaszkiewicz (1980), the strata in between them belong to the *Belemnitella junior* Zone. As discussed above, planktonic foraminifers indicate that the Chełm section should be correlated to the lower part of the Upper Maastrichtian, within the *Belemnitella junior* Zone. Consequently, the *Rugoglobigerina pennyi/Guembelitria cretacea* zonal boundary, because of the co-occurrence of *Globotruncana* and *Guembelitria cretacea*, should be shifted upward, *i.e.* within the lowest part of the *B. junior* Zone (Figs 8, 9).

Benthic foraminifers

Most species of benthic foraminifers recorded in the Chełm section have no stratigraphic value as they occur in at least two Cretaceous stages, except for *Anomalinoides acutus* (Plummer), *A. preacutus* (Vassilenko), *A. gankinoensis* (Neckaja), *Neoflabellina reticulata* (Reuss), *Pseudouvigerina cristata* (Marsson) and *Bolivinoides giganteus* (Hilterman & Koch), all of which indicating the Upper Maastrichtian (see Gawor-Biedowa, 1992; Beniamovskii & Kopaevich, 2002; Fig. 10).

Bolivinoides giganteus (Hilterman & Koch) is regarded by Gawor-Biedowa (1992) as the index species of the nominal subzone, which correlates to the upper part of the Upper Maastrichtian in the Polish Lowland (Fig. 10). In the Chełm quarry, *B. giganteus* co-occurs with macrofauna and microfauna indicative of the lower part of the Upper Maastrichtian, thus its range should be extended downward to the Lower-Upper Maastrichtian boundary (Fig. 10).

COMPARISON OF PLANKTONIC FORAMINIFERAL ASSEMBLAGES FROM THE CHEŁM SECTION AND THE MIDDLE VISTULA RIVER VALLEY

A comparison of ranges of planktonic foraminiferal species recorded in the Chełm section with those from the Middle Vistula River Valley makes it possible to correlate the Chełm section to the “classical” Middle Vistula River Valley section. However, the distribution of planktonic foraminifers depends on the depth of the water column in the basin (this specially applies to deep-dwelling morphotypes such as *Globotruncana* and *Contusotruncana*).

The planktonic foraminiferal assemblages from Lucimia (Middle Vistula River Valley) comprises the first specimens of *Guembelitria cretacea*, which co-occurs with representatives of *Heterohelix* and *Globigerinelloides* (*G. multispinus* last occurrence in the section), whereas *Globotruncana* and *Globotruncanella* are lacking (Fig. 11). The assemblages from Chotcza comprise the last *Globotruncana*, associated with *Globotruncanella petaloidea* and representatives of *Heterohelix* and *Globigerinelloides*, whereas *Guembelitria cretacea* is lacking (Fig. 11). It is remarkable that in the Chełm succession, the heterohelicids increase in abundance upward, *Globigerinelloides* are abundant throughout the entire section except of its uppermost part where they show a remarkable decrease, and *Globotruncana* occurs only in the lower part of the succession (level V, pr. V.8-V.10 and level VI, pr. VI.1) (Fig. 3). These changes of planktonic foraminiferal assemblages perfectly match that

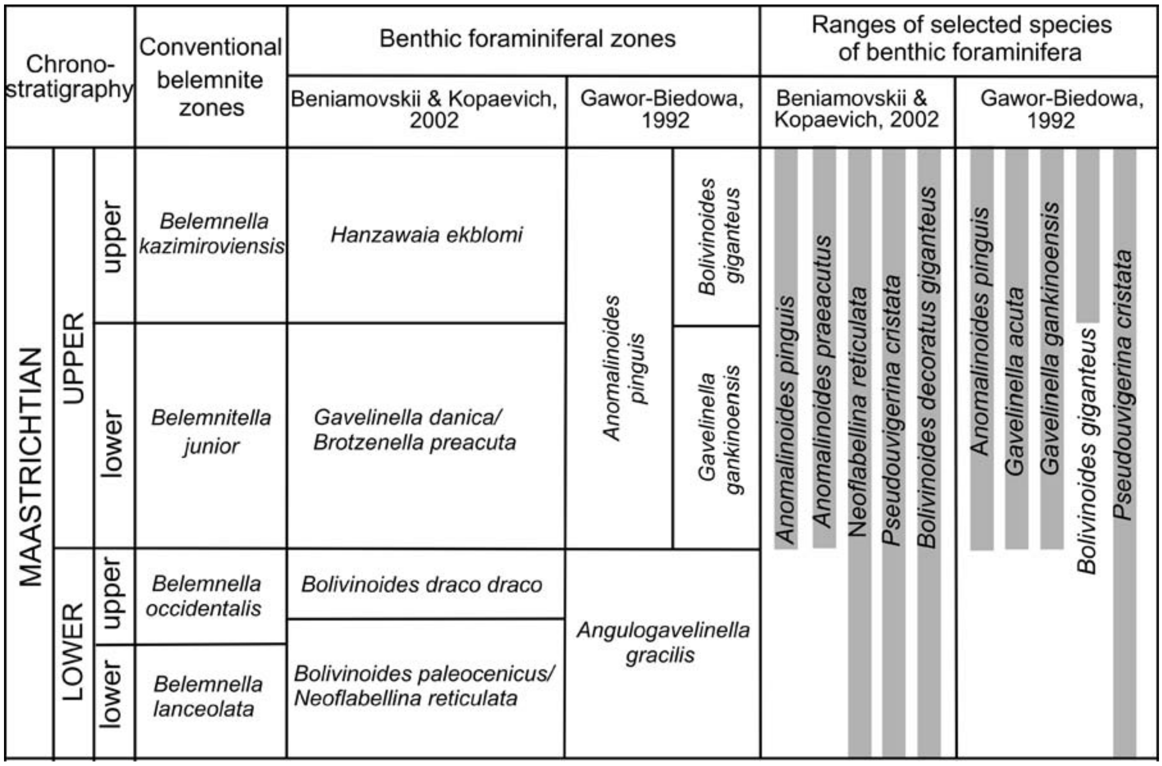

Fig. 10. Correlation of conventional belemnite zones and benthic foraminiferal zones, and ranges of selected species of benthic foraminifers

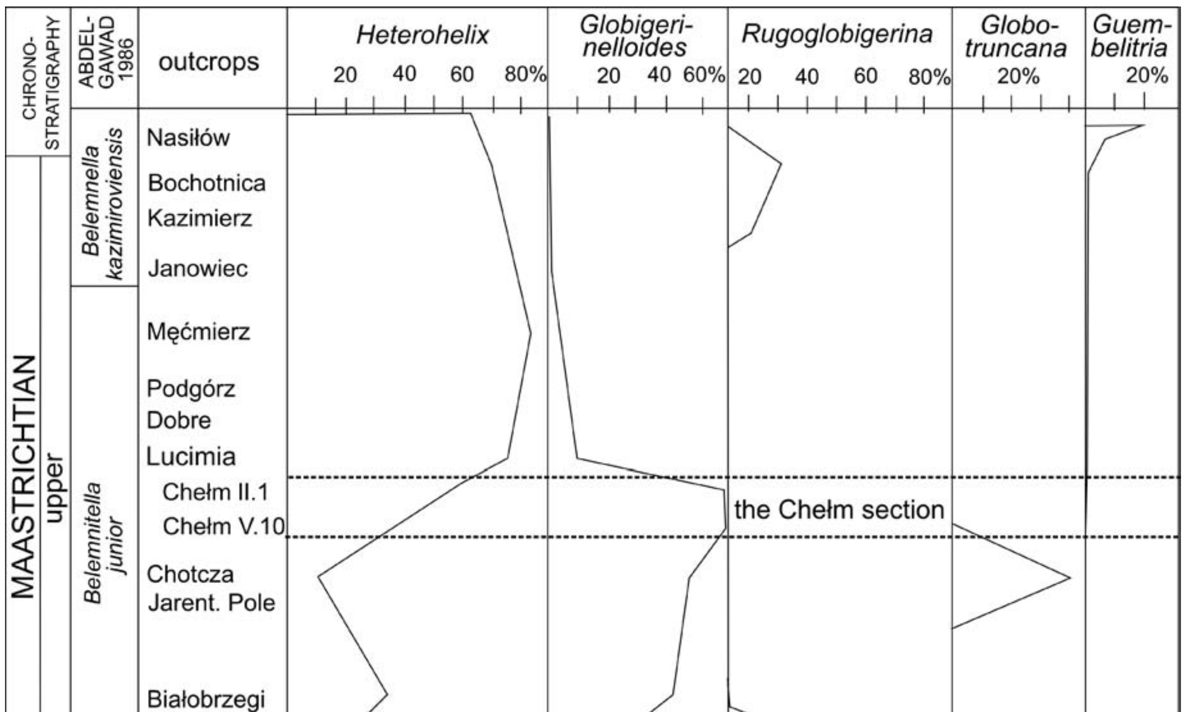

Fig. 11. Abundance (%) curves of selected genera within the planktonic foraminifer assemblages recorded in various outcrops of the Middle Vistula River Valley (after Peryt, 1980) and in the Chełm quarry section (this paper)

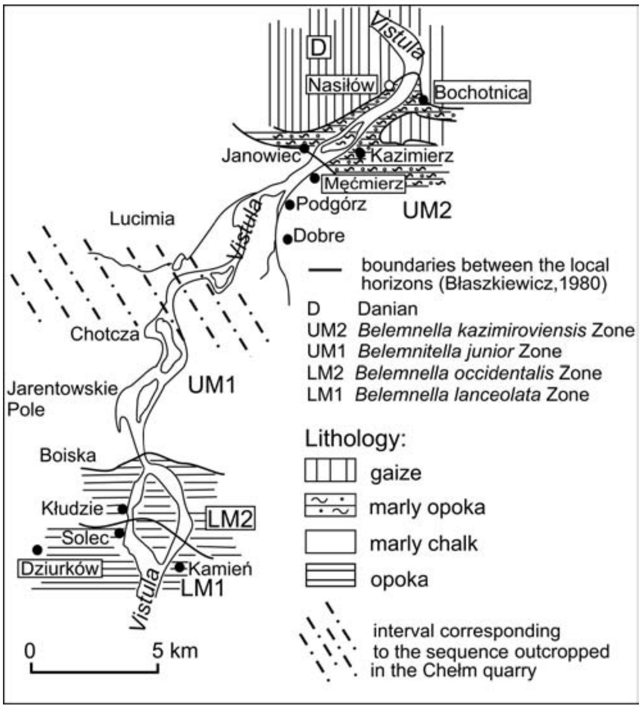

Fig. 12. The inferred location of the interval corresponding to the succession cropping out in the Chełm quarry in the Middle Vistula River Valley (geology after Błaszkiewicz, 1980)

interpolated for the Middle Vistula River Valley between the villages of Chotcza and Lucimia (Figs 11, 12).

The Middle Vistula River Valley section is not equally well exposed throughout, and most part of the *Belemnitella junior* Zone is covered by younger deposits. It seems likely that the interval of the Chełm section is not exposed in the Middle Vistula River Valley. On the other hand, a very similar pattern of changes in planktonic foraminiferal assemblages in both the Chełm section and the Middle Vistula sections enable us to suggest that the succession exposed in the quarry corresponds to the covered interval between Chotcza and Lucimia (Fig. 12).

INTEGRATION OF BIOSTRATIGRAPHICAL DATA

The ranges of benthic foraminifers of the Chełm section locate this section in the *Gavelinella danica/Brotzenella praeacuta* Zone of the European Boreal province as well as in the *Anomalinoides pinguis* Zone set for the Polish part of the European Boreal province (Fig. 10). The ranges of macrofauna locate the Chełm section in the lower part of the Upper Maastrichtian.

The ranges of planktonic foraminifers and the correlation with the Middle Vistula River Valley section locate the Chełm section within the middle part of the *B. junior* Zone (Figs 8, 9). If the range of the *B. junior* Zone in Poland is shorter than in Western Europe (Christensen, 1996) and spans the lower part of the zone (Jeletzky, 1951; Birkelund, 1957; Surlyk, 1970), the interval of the Maastrichtian succession located between Chotcza and Lucimia (Middle Vistula River valley) falls in the lowermost part of the Upper Maastrichtian, *i.e.* in the *Belemnitella junior-Spyridoceramus tegulatus* Zone. Therefore, the boundary between the *Rugoglobigerina pennyi* and *Guembelitria cretacea* zones would also fall within the *Belemnitella junior-Spyridoceramus tegulatus* Zone (Fig. 7).

CONCLUSIONS

Benthic foraminifers and macrofauna indicate that the chalk section at Chełm quarry represents the lower part of the Upper Maastrichtian, *i.e.*, *Gavelinella danica/Brotzenella praeacuta* Zone or the *Anomalinoides pinguis* Zone, based on benthic foraminifers, and the *Belemnitella junior-Spyridoceramus tegulatus* Zone based on ammonites, belemnites and bivalves.

Planktonic foraminifers make it possible to locate the studied section slightly above the boundary of the *Rugoglobigerina pennyi* and *Guembelitria cretacea* zones

The biostratigraphical correlation of the Chełm quarry section and the "classical" Middle Vistula River Valley section indicates that the equivalent interval of the former section is not exposed in the Middle Vistula River Valley, and that it would occur between the villages Chotcza and Lucimia within the lower part of the *Belemnitella junior* Zone *sensu* Błaszkiewicz (1980), *i.e.*, within the *Belemnitella junior-Spyridoceramus tegulatus* Zone *sensu* Schulz & Schmid (1983) (the lowest part of the Upper Maastrichtian).

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REFERENCES

Abdel-Gawad, G. I., 1986. Maastrichtian non-cephalopod mollusks (Scaphopoda, Gastropoda and Bivalvia) of the Middle Vistula Valley, Central Poland. *Acta Geologica Polonica*, 36: 69 –224.

Alexandrowicz, S. W., 1977. Sclerites of octocorals from the Upper Cretaceous of eastern Poland. *Journal of Paleontology*, 51: 687–692.

Beniamovskii, V. N. & Kopaevich, L. F., 2002. Benthic foraminiferid zonation in the Late Santonian–Maastrichtian of the European paleobiogeographical area (EPA). *Zentralblatt für Geologie und Paläontologie*, Teil I, 11-12: 1149–1161.

Birkelund, T., 1957. Upper Cretaceous belemnites from Denmark. *Biologiske Skrifter, Kongelige Danske Videnskabernes Selskab*, 9: 1–69.

Błaszkiewicz, A., 1966. Remarks on Campanian and Maastrichtian stratigraphy of the Middle Vistula River valley, Central Poland. (In Polish, English summary). *Kwartalnik Geologiczny*, 10: 1060–1071.

Błaszkiewicz, A., 1980. Campanian and Maastrichtian ammonites of the Middle Vistula River Valley, Poland: a stratigraphicpaleontological study. *Prace Instytutu Geologicznego*, 92: 1–63.

Christensen, W. K., 1996. A review of the Upper Campanian and Maastrichtian belemnite biostratigraphy of Europe. *Cretaceous Research*, 17: 751–766.

Christensen, W. K., Schmid, F. & Schulz, M.-G., 2004. *Belemnitella* from the Upper Maastrichtian of Hemmoor, Northwest Germany. *Geologisches Jahrbuch*, A 157: 11–22.

Dhondt, A. V., 1983. Tegulated inoceramids and Maastrichtian biostratigraphy. *Newsletters on Stratigraphy*, 12: 43–53.

Dubicka, Z., 2008. *Stratygrafia i sedymentacja osadów mastrychtu odsłoniętych w kamieniołomie cementowni Chełm (Lubelszczyzna)*. (In Polish). Unpublished M.Sc. thesis, Faculty of Geology, University of Warsaw, 135 ms. pp.

Gawor–Biedowa, E., 1992. Campanian and Maastrichtian Foraminifera from the Lublin Upland, Eastern Poland. *Palaeontologia Polonica*, 52: 3–187.

Harasimiuk, M., 1975. Relief evolution of the Chełm Hills in the Tertiary and Quaternary. (In Polish, English summary). *Prace Geograficzne Instytutu Geografii PAN*, 115: 1–108.

Harasimiuk, M., Henkiel A., Peryt, D., Rutkowski, J. & Wyrwicka, K., 1984. Wybrane zagadnienia utworów mezozoicznych i kenozoicznych w okolicy Rejowca i Chełma. (In Polish). In: Harasimiuk, M. (*ed.*), *Przewodnik 56 Zjazdu Polskiego Towarzystwa Geologicznego, Lublin, 6-8 września 1984*. Wydawnictwa Geologiczne, Warszawa: 143–163.

Jagt, J. W. M., 1999. Late Cretaceous–Early Palaeocene echinoderms and the K/T boundary in the south-east Netherlands and northeast Belgium – Part 1: Introduction and stratigraphy. *Scripta Geologica*, 116: 1–57.

Jeletzky, J. A., 1951. Die Stratigraphie und Belemnitenfauna des Obercampan und Maastricht Westfalens, Nordwestdeutschlands und Dänemarks, sowie einige allgemeine Gliederungs-Probleme der jüngeren borealen Oberkreide Eurasiens. *Beihefte zum Geologischen Jahrbuch*, 1: 1–142.

Keutgen, N., 1996. *Biostratigraphie, Paläoökologie und Invertebratenfauna des Untermaastricht von Aachen (Westdeutschland) und angrenzenden Gebieten (Südostniederlande, Nordostbelgien)*. Ph. D. Thesis. Rheinisch-Westfalische Technische Hochschule, 213 ms. pp.

Krassowska, A., 1997. Górna kreda. (In Polish). *Prace Państwowego Instytutu Geologicznego*, 153: 367–402.

Lendzion, K., 1960. Kreda. (In Polish). *Biuletyn Instytutu Geologicznego*, 165: 10–19, 115–119.

Loeblich, A. R., Jr. & Tappan, H., 1987. *Foraminiferal genera and their classification.* Van Nostrand Reinhold, New York, 1182 pp.

Machalski, M., 2005. Late Maastrichtian and earliest Danian scaphitid ammonites from central Europe: taxonomy, evolution and extinction. *Acta Palaeontologica Polonica*, 50: 653– 696.

Machalski, M., Jagt, J. W. M. & Dubicka, Z., 2008. Additional records of scaphitid ammonites from the basal upper Maastrichtian (Upper Cretaceous) of eastern Poland. *Bulletin Aardwetenschappen – Bulletin Sciences de la terre*, 78: 261–268.

Machalski, M., Jagt, J.W.M., Landman, N.H. & Motchurova-Dekova, N., 2007. The highest record of North American scaphitid ammonites in the European Maastrichtian (Upper Cretaceous) and their stratigraphical implications. *Acta Geologica Polonica*, 57: 160–185.

Peryt, D., 1980. Planktic foraminifera zonation of the Upper Cretaceous in the Middle Vistula River Valley, Poland. *Palaeontologia Polonica*, 41: 3–101.

Peryt, D., 1988. Maastrichtian extinction of planktonic foraminifera in Central and Eastern Poland. *Revista Española de Paleontología*, 3: 105–115.

Pióro, K., 2007. Wiek i paleośrodowisko depozycji górnokredowych utworów okolic Chełma i Rejowca w oparciu o zespoły otwornic. (In Polish). In: Harasimiuk, M., Brzezińska-Wójcik, T., Dobrowolski, R., Mroczek, P. & Warowna, J. (*eds*), *Budowa geologiczna regionu lubelskiego i problemy ochrony litosfery*. Wydawnictwo UMCS, Lublin: 57–62.

Pożaryska, K., 1954. O przewodnich otwornicach z kredy górnej Polski środkowej. (In Polish). *Acta Geologica Polonica*, 4: 249–276.

Pożaryski, W., 1997. Powaryscyjska tektonika obszaru świętokrzysko-lubelskiego na tle struktury podłoża. *Przegląd Geologiczny*, 45: 1265–1270.

Pożaryski, W., Brochwicz-Lewiński, W., Brodowicz, Z., Jaskowiak-Schoeneich, M., Milewicz, J., Sawicki, L. & Uberna, T., 1979. *Geological map of Poland and adjoining countries, without Cenozoic formations (without Quaternary in the Carpathians)*. Wydawnictwa Geologiczne, Warszawa.

Schulz, M. G., 1982. Erster Nachweis der Belemnitengattung *Belemnitella* (*B. pulchra* n.sp.) im mittleren Untermaastricht NW-Deutschlands. *Geologisches Jahrbuch*, A61: 279–293.

Schulz, M. G. & Schmid, F., 1983. Das Ober-Maastricht von Hemmoor (N-Deutschland): Faunenzonen-Gliederung und Korrelation mit dem Ober–Maastricht von Dänemark und Limburg. *Newsletters on Stratigraphy*, 13: 203–215.

Siemiradzki, J., 1909. *Geologia ziem polskich*, Tom II. *Formacye młodsze (kreda–dyluwium)*. (In Polish). Muzeum imienia Dzieduszyckich, Lwów, 584 pp.

Sujkowski, Z., 1931. Petrografia kredy Polski. (In Polish). *Sprawozdania Państwowego Instytutu Geologicznego*, 6: 485–628.

Surlyk, F., 1970. Die Stratigraphie des Maastricht von Dänemark und Norddeutschland aufgrund von Brachiopoden. *Newsletters on Stratigraphy,* 1: 7–16.

Świdrowska, J., 2007. Kreda w rejonie lubelskim – sedymentacja i jej tektoniczne uwarunkowania. (In Polish). *Biuletyn Państwowego Instytutu Geologicznego*, 422: 63–78.

Voigt, S., Wagreich, M.., Surlyk, F., Walaszczyk, I., Uličný, D., Čech, S., Voigt, T., Wiese, F., Wilmsen, M., Niebuhr, B., Reich, M., Funk, H., Michalík, J., Jagt, J.W.M., Felder, P.J. & Schulp A.S., 2008. Cretaceous. In: McCann,T. (*ed.*), *Geology of Central Europe*, Volume 2: *Mesozoic and Cenozoic*. The Geological Society, London: 923–997.

Witwicka, E,. 1958. Stratygrafia mikropaleontologiczna kredy górnej wiercenia w Chełmie. (In Polish). *Biuletyn Instytutu Geologicznego*, 121: 177–267.